Computers in Human Behavior 39 (2014) 356–367

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Can the use of cognitive and metacognitive self-regulated learning strategies be predicted by learners' levels of prior knowledge in hypermedia-learning environments?

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ARTICLE INFO

Article history:

Keywords:
Metacognition
Prior knowledge
Self-regulated learning
Hypermedia-learning environments

ABSTRACT

Research on self-regulated learning (SRL) in hypermedia-learning environments is a growing area of interest, and prior knowledge can influence how students interact with these systems. One hundred twelve ($N = 112$) undergraduate students' interactions with MetaTutor, a multi-agent, hypermedia-based learning environment, were investigated, including how prior knowledge affected their use of SRL strategies. We expected that students with high prior knowledge would engage in significantly more cognitive and metacognitive SRL strategies, engage in different sequences of SRL strategies, spend more time engaging in SRL processes, and visit more pages that were relevant to their sub-goals than students with low prior knowledge. Results showed significant differences in the total use of SRL strategies between prior knowledge groups, and more specifically, revealed significant differences in the use of each metacognitive strategy (e.g., judgment of learning), but not each cognitive strategy (e.g., taking notes) between prior knowledge groups. Results also revealed different sequences of use of SRL strategies between prior knowledge groups, and that students spent different amounts of time engaging in SRL processes; however, all students visited similar numbers of relevant pages. These results have important implications on designing multi-agent, hypermedia environments; we can design pedagogical agents that adapt to students' learning needs, based on their prior knowledge levels.

1. Introduction

Self-regulated learning, SRL, is an important educational construct that has been shown to be effective for students as they learn and study various subjects (Azevedo, 2005; Azevedo, 2007; Winne & Perry, 2000; Zimmerman & Schunk, 2011). When students self-regulate their learning, they are playing an active role in the learning process by engaging in planning, goal-setting, and other cognitive and metacognitive processes (Azevedo, 2005). Research has found that when students engage in self-regulated learning, they achieve high learning outcomes (Azevedo et al., 2013; Greene & Azevedo, 2010). It is, therefore, important for students to develop and use self-regulated learning skills, such as planning and monitoring, and strategies, such as judgment of learning and summarizing, in order to maximize their learning potential.

Despite increasing evidenc for the effectiveness of self-regulated learning on students' learning outcomes (Azevedo & Feyzi-Behnagh, 2010; Azevedo, Feyzi-Behnagh, Duffy, Harley, & Trevors, 2012), research has also revealed that students do not enact these effective SRL strategies during learning (Azevedo, 2005; Azevedo, Feyzi-Behnagh, et al., 2012). Interdisciplinary researchers have been designing and developing computer-based learning environments (CBLEs; e.g., multimedia, hypermedia, intelligent tutoring systems, multi-agent systems) to foster and promote effective self-regulated learning in students as they learn about various topics such as biology, physics, and ecology (Azevedo & Aleven, 2013; Azevedo, Moos, Johnson, & Chauncey, 2010; Azevedo et al., 2013; Biswas, Jeong, Kinnebrew, Sulcer, & Roscoe, 2010; D'Mello et al., 2013; Graesser, Chipman, King, McDaniel, & D'Mello, 2007; Jonassen & Land, 2012; Lajoie et al., 2013; Lester, Mott, Robinson, & Rowe, 2013; Woolf, 2009).

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http://dx.doi.org/10.1016/j.chb.2014.07.018
0747-5632/

Some CBLEs are agent-based, meaning they are programmed to include one or several pedagogical agents, PAs, who are present to assist students by providing scaffolding and feedback during learning, problem solving, strategy training, and skill acquisition (Azevedo et al., 2012; Biswas et al., 2010; D'Mello et al., 2013; Graesser & McNamara, 2010; Lester et al., 2013). In addition to content learning, these agents are programmed to assist learning about different aspects of SRL, such as planning, goal-setting, metacognitive monitoring, strategy use, and reflection (see Azevedo & Aleven, 2013; Azevedo, Feyzi-Behnagh, et al., 2012). Research has shown that the use of PAs can be effective for learners because providing students with the appropriate scaffolding can help them to better learn (Kinnebrew, Biswas, Sulcer, & Taylor, 2013) and, more specifically, to self-regulate their learning (Azevedo, Feyzi-Behnagh, et al., 2012; Graesser & McNamara, 2010; Winters, Greene, & Costich, 2008). The role of prior knowledge is a critical individual differences variable that has not been adequately examined in the context of SRL and learning with multi-agent systems. Results will contribute to theoretical (e.g., understanding the deployment of SRL processes based on prior knowledge) and educational (e.g., providing a dynamic assessment and differential scaffolding based on learners' prior knowledge) implications to SRL, which can assist researchers in designing CBLEs that adapt to student characteristics, such as level of prior knowledge.

The focus of this study is to assess how students' prior knowledge can impact the way they self-regulate their learning in a CBLE, with the assistance of pedagogical agents. Prior knowledge of the domain can greatly affect how students engage in different SRL processes and use learning strategies (Moos & Azevedo, 2008; Shapiro, 2004); thus, when creating these environments, it is important to consider how students' prior knowledge of the domain can potentially influence the SRL skills and strategies (which can be metacognitive or cognitive) that they use. For this study, we acknowledged past findings regarding the importance of prior knowledge, and thus assessed how prior knowledge of the circulatory system influenced how students used cognitive and metacognitive SRL strategies as they learned with MetaTutor, a multi-agent, adaptive hypermedia-learning environment (Azevedo et al., 2010; Azevedo, Cromley, Moos, Greene, & Winters, 2011; Azevedo, Feyzi-Behnagh, et al., 2012, 2013; Azevedo, 2009).

1.1. Theoretical framework

In our analyses of self-regulated learning, we view SRL as an event that temporally unfolds in real time (Azevedo et al., 2010; Azevedo et al., 2013; Winne & Perry, 2000). As our theoretical model of SRL, we used Winne and Hadwin's Information-Processing Model (1998, 2008), according to which learning occurs in four basic phases—definition of the task, setting goals and planning, studying tactics, and adaptations—and information processing occurs within each learning phase (Winne & Hadwin, 1998; 2008). In Phase 1, learners assess the task at hand and determine the environmental factors that are available to help accomplish the task. Phase 2 involves planning and goal-setting, in which learners set goals that are necessary to accomplish the task. In addition, learners plan the appropriate subtasks needed to complete the sub-goals that were set at the beginning of the phase. Phase 3 involves the learners employing the strategies that they planned to engage in during the second phase. In addition, the learners monitor their progress toward achieving the goals that have been set. Lastly, Phase 4 is characterized by a reflection of what was accomplished in Phases 1–3. Learners make appropriate adaptations to plans and goals that were set, which can be based on the learners' modified understanding of the task.

It is expected that students with high prior domain knowledge will progress through each stage differently than students with low prior knowledge of the domain on which the task focuses. In Phase 1 (defining the task), students with high prior knowledge will not differ from students with low prior knowledge in terms of defining what the task is asking of them; however students with high prior knowledge will be more aware of the contextual factors, which can be used as resources in accomplishing the task, compared to students with low prior knowledge, who will have difficulty identifying the appropriate environmental factors. For example, students with high prior knowledge might recall how they approached a similar problem in the past, but students with low prior knowledge will not make this connection between present and past problems. In the second phase (setting goals and planning), students with high prior knowledge will not have difficulties planning or creating the sub-goals necessary to achieve the task; however since students with low prior knowledge are not familiar with the domain, they will experience difficulties in creating the sub-goals needed to accomplish the task. For example, students with high prior knowledge know that if they are learning about the circulatory system, they will need to create a sub-goal that either relates to prior knowledge or goes beyond their prior knowledge (of the circulatory system) and deals specifically with the overall learning goal. Students with low prior knowledge, however, might experience difficulties when creating and prioritizing relevant sub-goals, given their lack of domain knowledge. For Phase 3 (studying tactics), both prior knowledge groups will be able to deploy the strategies that they have set; however students in the high prior knowledge group will differ by deploying more sophisticated and effective use of these strategies. For example, students in both groups might have planned to take notes, but students with high prior knowledge might translate the notes into their own words, whereas students with low prior knowledge might copy the words verbatim from the text. In addition, high prior knowledge students will be able to metacognitively monitor their emerging understanding of the topic more accurately than those with low prior knowledge. Finally, in Phase 4, students with high prior knowledge will be able to reflect on their learning and adjust their understanding of the question, whereas students with low prior knowledge might not be able to make such a reflection. For example, students with high prior knowledge might have planned to spend a particular amount of time achieving a sub-goal; however during reflection, they might realize that they need more time to accomplish another sub-goal. Students with low prior knowledge, however, might not be able to reflect on the time they allotted to completing the sub-goals.

This study focuses on the role of students' prior knowledge on their use of self-regulated learning strategies, and whether we see significant differences between high and low prior knowledge groups. Winne and Hadwin's model (2008) emphasizes the role of prior knowledge as a key factor in self-regulated learning; however, no specific framework or hypotheses have been generated that address the role of prior knowledge in self-regulated learning with CBLEs. Thus, our study provides results that can be used to facilitate the development of a framework for the role of prior knowledge in self-regulated learning with hypermedia (Azevedo et al., 2013).

Based on the existing literature on prior knowledge and Winne and Hadwin's SRL model, we make two assumptions. First, learners with high prior domain knowledge (HPK) will be more effective at self-regulating their learning, compared to students with low prior domain knowledge (LPK), because they have more relevant domain knowledge that allows them to anchor new knowledge to existing knowledge (Mayer, 2004). Second, learners with high prior domain knowledge will be more effective at self-regulating their learning, compared to students with low prior domain knowledge, because